IN THE SPECIFICATION:

Please replace paragraph [0004] with the following paragraph:

[0004] As layers of materials are sequentially deposited and removed, the uppermost surface of the substrate may become non-planar across its surface and require planarization. An example of a non-planar process is the deposition of copper films with [[the]] an ECP process in which the copper topography simply follows the already existing non-planar topography of the wafer surface, especially for lines wider than 10 microns. Planarizing a surface, or "polishing" a surface, is a process where material is removed from the surface of the substrate to form a generally even, planar surface. Planarization is useful in removing undesired surface topography and surface defects, such as rough surfaces, agglomerated materials, crystal lattice damage, scratches, and contaminated layers or materials. Planarization is also useful in forming features on a substrate by removing excess deposited material used to fill the features and to provide an even surface for subsequent levels of metallization and processing.

Please replace paragraph [0032] with the following paragraph:

[0032] Generally, the electrochemical mechanical polishing (ECMP) station 100 comprises a polishing head 130 adapted to retain the substrate 113. Illustratively, the polishing head 130 is a cantilever mounted to a carousel 111 by a brace [[137]] 127. The carousel 111 operates to rotate the polishing head 130 to a position over various stations, including the ECMP station 100. Examples of embodiments of polishing heads 130 that may be used with the polishing apparatus 100 described herein are described in United States Patent No. 6,024,630, issued February 25, 2000 to Shendon, *et al.* One particular polishing head that may be adapted to be used is a TITAN HEAD™ wafer carrier, manufactured by Applied Materials, Inc., located in Santa Clara, California.

Please replace paragraph [0033] with the following paragraph:

[0033] The ECMP station 100 further includes a basin 102, an electrode 104, polishing medium 105, a pad support disc 106 and a cover 108. In one embodiment, the basin 102 is coupled to a base 107 of the polishing apparatus 100. The basin 102, the cover 108, and the disc 106 may be movably disposed relative to the base 107 <u>by a pneumatic cylinder 128</u>. Accordingly, the basin 102, cover 108 and disc 106 may be axially moved toward the base 107 to facilitate clearance of the polishing head 130 as the carousel 111 indexes the substrate 113 between the ECMP 100 and other polishing stations (not shown).

Please replace paragraph [0060] with the following paragraph:

[0060] In one embodiment, the polishing station 300 includes a reference electrode. For example, a reference electrode 310A may be disposed between the disc 106 and the counter electrode 104. More generally, a reference electrode may be at any location in the basin as long as the reference electrode is submerged within the electrolyte 120. For example, a reference electrode 310B is shown suspended between a sidewall of the basin 102 and the polishing medium 105. The reference electrode acts to maintain a constant electrochemical potential on the substrate. Accordingly, the provision of the reference electrode makes the removal rate independent from the changes in the conductivity in the current loop, which may <u>be</u> caused by the deposition of loose copper on the counter electrode 104 for instance. The reference electrode may be made of a very thin metal wire, such as a wire made of platinum, and is connected to the power supply 302.

Please replace paragraph [0061] with the following paragraph:

[0061] The operation of the polishing system 300 is controlled by a control system 312. In one embodiment, the control system 312 includes a controller 314 and an

endpoint detector 316. The controller 314 is operably connected to each of the devices of the polishing system 300, including the power supply 302, the fluid delivery system 172, the motor 124 and the carrier head 130. The endpoint detector 316 is configured to monitor signal characteristics of the signal provided by the power supply 302. To this end, the endpoint detector 316 may be electrically connected to a meter 318 disposed in a power line of the power supply 302. Although ~~show~~ shown separately from the power supply 302, the meter 318 may be an integral part of the power supply 302. In one embodiment, the meter 318 is an amp meter configured to measure current. In another embodiment, the meter 318 is a voltage meter configured to measure voltage. In still another embodiment, the meter is configured to measure voltage and current. A reading taken from the meter 318 may then be used by the endpoint detector 316 to determine whether a criterion has been satisfied. One criterion is whether the substrate has been sufficiently polished (i.e., whether a polishing endpoint has been reached). If a polishing endpoint has been reached, the endpoint detector 316 may notify the controller 314, which may then issue one or more control signals to initiate additional steps and/or halt the polishing of the substrate.

Please replace paragraph [0063] with the following paragraph:

[0063] An endpoint detection operation will now be described with reference to FIGS. 4A-C. Referring ~~first~~ to FIG. 4A, a side view of the substrate 113 and the polishing medium 105 is shown. The polishing medium 105 is shown submerged in the electrolyte 120 which is made an ionic conductor by application of a voltage or current from the power supply 302. The substrate 113 is shown located over the electrolyte 120 and moving downward toward the polishing medium 105. In general, the substrate 113 includes a base material 402 (typically made of silicon) having features formed therein. The base material 402 may be covered by multiple layers of dielectric materials, semiconducting materials and conducting materials. The outermost metal layer 406 has been previously deposited in the features 404 and over the previous dielectric, semiconducting and conductive layers. Illustratively, the metal layer 406 is

copper. A passivation layer 408 is formed over the metal layer 406. The passivation layer 408 is selected to ensure that polishing occurs primarily where contact is made with the polishing medium 105. Passivation agents which are part of the conductive electrolyte will passivate the recess areas of the incoming metal layer to be polished. Illustrative passivation agents include BTA, TTA, etc. Accordingly, as shown in FIG. 4B, the passivation layer 408 is not present at the interface of the polishing medium 105 and the metal layer 406. The polishing which occurs in FIG. 4B is a combination of mechanical polishing (as a result of relative movement between the substrate 113 and the polishing medium 105) and anodic dissolution (as a result of chemical interaction between the substrate 113 and the electrolyte 120).

Please replace paragraph [0065] with the following paragraph:

[0065] Referring ~~out~~ to FIG. 5, a curve 500 is shown graphically illustrating the change in the electropolishing current (provided by the power supply 302) with respect to time. The current value is indicated on a vertical axis while time is indicated on the horizontal axis. Throughout the polishing cycle exemplified by curve 500, the power supply 382 maintains a substantially constant voltage. This manner of operation is referred to herein as "voltage mode" operation, since a constant voltage is applied to the polishing cell. It should be noted that the current curve directly generated from the meter 318 may not be as smooth as shown in FIG. 5, but the signal can be smoothed either by an electronic filter or software averaging.

Please replace paragraph [0070] with the following paragraph:

[0070] In one aspect, the purpose of switching from a higher voltage value to a lower voltage value is to increase the wafer throughput. Specifically, the higher voltage value corresponds to a higher current ~~and, thus,~~ and thus, a higher removal rate. However, while a higher removal rate is preferable with regard to throughput, the higher voltage value may not provide the best results in ~~term~~ terms of copper dishing, copper

residuals, surface finish, etc. Accordingly, once the remaining copper layer becomes very thin but still continuous, the voltage is then switched to the lower value. Illustratively, the switch is timed according to some predetermined time value selected to optimize throughput. In this manner, the process can be optimized for throughput as well as results (e.g., film quality).

Please replace paragraph [0071] with the following paragraph:

[0071] After the voltage is switched to the second voltage value, the current is again maintained at a substantially constant value [[I1]] $\underline{I_1}$. Illustratively, the substantially constant current value is maintained for a time t2 to t3. At time period t3, a second reduction in the current is observed. The reduction in current is monitored by the endpoint detector 316 until a polishing endpoint is detected at time t4. An over polishing step may then be maintained for a time period t4 to t5, after which the polishing cycle is complete and the substrate may be removed from the polishing station for subsequent processing.

Please replace paragraph [0073] with the following paragraph:

[0073] Accordingly, regardless of the mode of operation (i.e. current mode or voltage mode), a polishing endpoint is detected according to signal characteristics of a signal provided by the power supply 302. In each case, the same or similar algorithms may be used to detect the endpoint. In one embodiment, well-known algorithms may be used for detecting a predetermined rate of change of the signal characteristic. For example, it is contemplated that the etching endpoint detection algorithms used in etching systems may be adapted for use with the present invention. In such etching systems the wavelength of reflected light is typically monitored. Changes in the wavelength [[of]] indicate when a material has been sufficiently etched. Accordingly, one embodiment of the present invention advantageously utilizes these and similar algorithms to advantage.

More generally, however, persons skilled in the art will recognize other algorithms and techniques which may be used to advantage.

Please replace paragraph [0075] with the following paragraph:

[0075] At the beginning of the process, (as soon as the power supply 302 is turned ON), the current is at a value [[I1]] $\underline{I_1}$. The height of a first pair of windows 510A-B is set so that I1 must fall within a current predetermined range. If [[I1]] $\underline{I_1}$ does not fall within the window height, the polishing station ohmic resistance is not within specification and is not behaving properly. In this event, the process is automatically stopped by the endpoint detector 316.

Please replace paragraph [0076] with the following paragraph:

[0076] During proper operation, the current is stable between t0 and t1. That is, the endpoint curve 500 enters the windows 510A-B from the side and exits the windows 510A-B from the side. At time t1, the metal layer to be polished becomes discontinuous, the current drops and the current curve 500 exits a window 510C from the bottom. The curve 500 exiting the bottom of the window 510C indicates a current drop to the endpoint detector 316. The signal exits the bottom of a number of windows 510D-E until all the remaining copper patches have been polished (i.e., until time t2). At time t2, there is no more copper to polish and the current is stable again [[I2]] $\underline{I_2}$. Accordingly, the curve 500 exits from the side of the window 510F and the endpoint detector 316 detects the endpoint of the process at t2. The current [[I2]] $\underline{I_2}$ corresponds to the situation in which no metal ions (or a negligible amount of metal ions) are being released in the electrolyte. As such, [[I2]] $\underline{I_2}$ is typically very small (e.g., a few mAmps) compared to [[I1]] $\underline{I_1}$ (e.g., a few Amps). An overpolishing step can be done until time t3 to remove any residues.

Please replace paragraph [0089] with the following paragraph:

[0089] The current/removal rate relationship may be different depending on whether the wafer is a blanket wafer or a patterned wafer and depending on chemistry. In any case, the current/removal rate relationship can be obtained theoretically if the reaction scheme is known. For example, assume that it is known that only Cu^{++} (and not Cu^{+}) is removed for a given process. Assume further that a uniform removal rate of 1000 Å/min over a 200 mm wafer (surface area = 314 cm^2) has been measured for a wafer. It is known that for a copper crystal: a=b=c=361.49 pm = 3.6149 Å. Thus, the volume of a unit cell is 47.23 $Å^3$. Since there are four (4) atoms in a unit cell and two (2) charges per unit cell, the total charge per unit cell removed is: 4atoms*2charges*$1.6e^{-19}$ C. Further, since the volume of 1000 Å is $314e^{19}$ $Å^3$, the number of unit cells per 1000 Å is $314*e^{19}/47.23 = 6.64e^{19}$. The total charge removed is therefore $6.64e^{19}$ * (4atoms*2charges*$1.6e^{-19}$ C) = 85 C/min. Accordingly, a removal rate of 1000A/min corresponds to 1.42 Amps of Cu^{++} current. For a ~~200mm~~ 200 mm wafer, then, the current/removal relationship is ~~1.4Amps~~ 1.4 Amps per kAngstrom/min. In this manner, the current/removal rate relationship may be determined for a desired range of current values and removal rates.